Rocky Mountains Southwest Great Plains

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# Understory Cover-Biomass Relationships in the Front Range Ponderosa Pine Zone

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Generalized relationships between cover and biomass for three understory plant groups (grasses, forbs, shrubs) were examined across 30 ponderosa pine sites along the Front Range of Colorado and Wyoming. Sixteen sites were dominated by grass/forbs and 14 by shrubs. For each plant group a linear regression estimator forced through the origin provided a prediction comparable to one with a Y-intercept. Estimates of $R^2$ for the grass, forb, and shrub plant groups were 0.80, 0.62, and 0.81, respectively. These analyses show that regional-level Forest Survey data can be useful to forest and range resource planners and others needing to translate understory cover into biomass over large-scale areas of the ponderosa pine zone.



**Keywords:** Biomass prediction, indirect measurement, linear regression, Rocky Mountains, Colorado, Wyoming

## Management Implications

The 1989 National Assessment of the U.S. Forest and Rangeland Situation required by the Resources Planning Act of 1974, like previous ones, will utilize regional classification systems as bases for prognoses of various outputs. It is important that all available multiresource information, especially that capable of providing or validating estimates of joint production in response to management practices, be available to those involved in the assessment process. These analyses show that understory cover data, collected by Forest Survey units, are capable to being translated into biomass estimates. Linear models forced through the origin can adequately describe cover-biomass relationships at the forest level.

## Introduction

Forage biomass is an important measure of vegetative species composition on rangeland ecosystems, and it can be a useful estimator of forage production capability (Mitchell 1983). Biomass is best measured directly, or with some other sampling procedure that includes direct estimates, such as double sampling. However, biomass estimates are often too time consuming to obtain, especially when large, multiresource data sets are involved. Consequently, various measures of cover have been developed to estimate biomass of herbage and browse species over the years (Medin 1960, Payne 1974, Humphrey 1985).

Theoretically, biomass should increase exponentially as cover approaches 100%, just as does the relationship between frequency and density (Greig-Smith 1964). With few exceptions, however, studies relating cover to biomass have used linear regression models, and their results have been accepted as adequate within the range of canopy cover studied.

Previous researchers, such as Payne (1974) and Humphrey (1985), have derived equations for individual species within specified sites or limited geographic areas; however, such models are only useful to users within the bounds of these limits. Regional data sets of plant cover require a different approach. If specific information on all sites within a forest is available, model outputs from species/locations can be summed for the desired estimate. Alternatively, if these data are not available, more

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generalized models must be used. In the first approach, the standard errors of individual models are relatively small, but are collectively additive. The standard error of more generalized models will be individually larger, but, collectively, they may be similar.

Multiresource data on a forest or regional scale are needed for developing and validating models that depict the responses of these resources to various land management planning strategies. At such a hierarchical level, representing a spatially large, low-frequency system (Allen et al. 1984), dynamics associated with individual understory species are filtered out; therefore, a more appropriate scale is necessary. One way to attain this scale is by classifying understory vegetation into grasses, forbs, and shrubs. At this level different species fill the same niche in terms of dominance and forage supply; hence, the life-form group is a logical structure for observing understory behavior.

In response to provisions of the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), as amended by the National Forest Management Act of 1976 (NFMA), USDA Forest Service Survey Units are collecting multiresource data on a recurring basis from permanent sample sites situated across the forests and woodlands of the United States. The Survey Unit at the Intermountain Station has been given responsibility for this effort throughout the Rocky Mountain area (USDA Forest Service 1985). Its inventory approach—one commonly used by Forest Service and other units conducting regional surveys—involves the estimation of understory abundance by cover of three plant groups: grasses, forbs, and shrubs (O'Brien and Van Hooser 1983). For many areas, data sets compiled by Forest Survey units constitute the only source of multiresource data available that are not dedicated to specific sites.

In the summer of 1984, 30 stands along the Rocky Mountain Front Range in Wyoming and Colorado dominated by ponderosa pine (*Pinus ponderosa* Dougl.) were sampled for understory vegetation variables (fig. 1). The sampling population represented the Douglas-fir/pine forest defined by Küchler (1964), whose classification was used by the Forest Service in the previous RPA National Assessment (USDA Forest Service 1980). The Douglas-fir/pine forest occupies nearly 3.5 million hectares in the western United States, primarily within Colorado, New Mexico, and Wyoming. Production estimates for such a regional classification, therefore, are well-suited to make use of associated Forest Survey field data.

The sample areas were selected from the larger population of Forest Survey sites on the basis of forest type and accessibility; a further criterion was the requirement to adequately sample the latitudinal extent of the Front Range. One objective of this survey, reported here, was to analyze the relationship between cover and biomass at such a regional level.


**Figure 1.—Map of Rocky Mountain region showing location of sample sites used in understory cover-biomass study.**

## Methods

At each of the 30 stands sampled, 30 observations of understory cover and biomass were systematically obtained along a hexagonal-shaped transect. The transect was designed so that it fit between the five permanent circular Forest Survey plots placed on a site, while still providing an adequate depiction of that stand (fig. 2). Estimates of canopy cover and biomass were made for each understory species constituting at least 5% of the site and, collectively, for grasses, forbs, and shrubs. All data were obtained using a single field crew of two individuals, one of whom did all the estimating in order to preclude sampling bias.

In this study, cover was defined as a vertical projection of the canopy's outline onto the ground within the plot frame (Daubenmire 1959). Cover was estimated numerically in percent with as much precision as practicable. It was expected that the observers would attain increased precision as cover approached both 0 and 100%, as proposed by Hatton et al. (1986).

Biomass (kg/ha air-dry) was estimated using a double sampling technique (Wilm et al. 1944). The sample size of 30 observations per stand allowed biomass to be estimated within 20% of the mean with 80% reliability. The optimum ratio of clipped to estimated plots was 1:5, derived from a preliminary sample. Shrub biomass was based on current years' growth of twigs and leaves. The

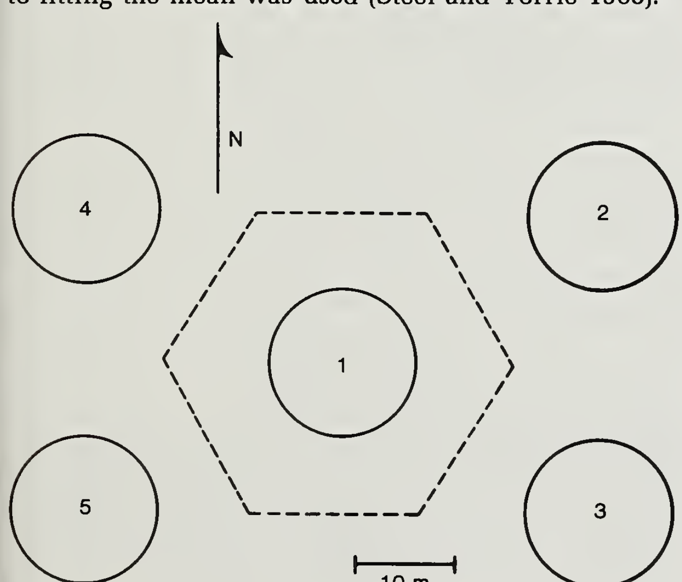
double sampling estimate for mean biomass ($\hat{Y}_N$) on a given site was

$$\hat{Y}_N = \bar{Y} + b(\bar{X}_n - \bar{X}_N)$$

where $\bar{Y}$ = mean biomass of clipped plots, b = slope of regression between $X_i$ and $Y_i$, $\bar{X}_N$ = mean biomass of all estimated plots, and $\bar{X}_n$ = mean biomass of estimated plots that were clipped.

After the data were collected, the stands sampled were classified as to whether they were dominated by grasses or forbs (16 stands) or by shrubs (14 stands). Shrub sites can be easily identified by their dominance by shrubs, especially bitterbrush (*Purshia tridentata* (Pursh) D C.) and mountain-mahogany (*Cercocarpus montanus* Raf.). Daubenmire and Daubenmire (1968) had already divided the habitat types within the ponderosa pine series into these two groups based on synecological considerations: (1) they tend to be mutually exclusive in terms of abundance; (2) the dichotomy is easily identifiable on the ground; and (3) their different life-forms provide different relationships between cover and biomass. For planning purposes on a regional scale, as addressed in this study, shrubs provide all but a negligible proportion of the forage supply on shrub sites. The same assumption can be made for grasses and forbs in stands dominated by these two species groups.

Relationships between cover and biomass were evaluated for grasses and forbs on the 16 grass/forb sites, and for shrubs on the 14 shrub sites using linear regression after observing scattergrams for evidence of nonlinearity (figs. 3–5). Regressions were forced through the origin to eliminate situations where positive or negative biomass was predicted from zero cover. To test the hypothesis that the regressions were actually through the origin, an F-test for the reduction in sum of squares due to fitting the mean was used (Steel and Torrie 1960).




Hexagonal sampling design

**Figure 2.—Depiction of Intermountain Station Forestry Survey plot design and transect used in understory cover-biomass study.**

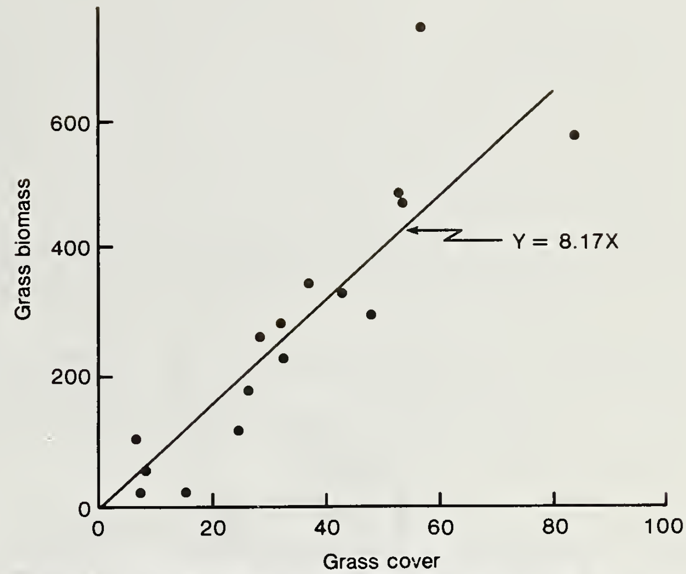



**Figure 3.—Relationship between grass cover and biomass on 16 sites in the Front Range ponderosa pine zone.**

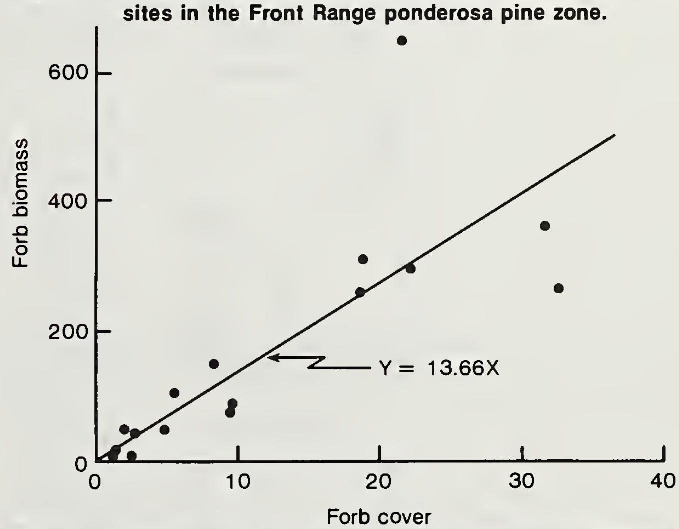



**Figure 4.—Relationship between forb cover and biomass on 16 sites in the Front Range ponderosa pine zone.**

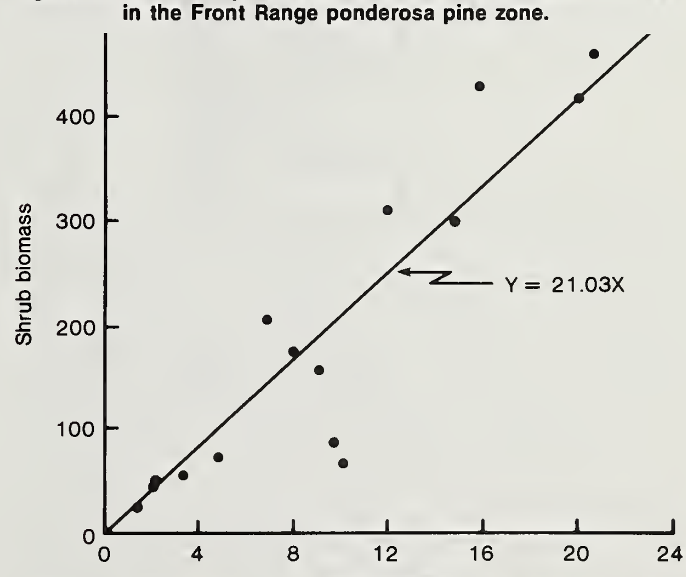



**Figure 5.—Relationship between shrub cover and biomass on 14 sites in the Front Range ponderosa pine zone.**

## Results and Discussion

Summary statistics of the three life-forms are shown below. Forcing the regression models through the origin had a negligible effect in each of the three cases; i.e., the reduction in sum of squares due to fitting the mean was insignificant ($P < .01$). An estimator that converges upon the origin (0,0) is more acceptable from a biological perspective, because it eliminates the possibility of having a positive or negative biomass at zero cover. Therefore, the forced functions are more suitable for portraying the cover-biomass relations examined in this study.

| | Mean | S.E. |
|---|---|---|
| **Grass/Forb Sites (n = 16)** | | |
| **Grass** | | |
| Cover | 34.9 | 5.26 |
| Biomass | 282.8 | 51.65 |
| **Forbs** | | |
| Cover | 12.1 | 2.67 |
| Biomass | 171.8 | 43.81 |
| **Shrub Sites (n = 14)** | | |
| Cover | 8.6 | 1.54 |
| Biomass | 174.5 | 39.24 |

The regression models for predicting standing crop biomass of grasses, forbs, and shrubs, shown below, possess two meaningful attributes. First, cover explained approximately 80%, 62%, and 81%, respectively, of the variation found in biomass. This relatively low coefficient of determination for forbs was expected because of wide multiformity in their life-form. For example, sites with a preponderance of prostrate, low-density forbs, such as *Artemisia ludoviciana* Nutt., tended to fall well below the regression line. One site, dominated by larger, thick-stemmed forbs like *Geranium fremontii* Torr., was found well above the regression line (fig. 4). Second, the slopes of the models appeared to represent the degree of vertical distribution (shrubs> forbs> grasses) more than the specific density of the respective life-form groups.

| Life-form | Slope (b) | $S_{y \cdot x}$ | $R^2$ |
|---|---|---|---|
| Grasses | 8.17 | 96.4 | 0.80** |
| Forbs | 13.66 | 107.7 | 0.62** |
| Shrubs | 21.03 | 64.8 | 0.81** |

** Significant at $P < 0.01$

## Conclusions

Forest Survey data sets, like others containing measures of understory vegetation based only upon canopy cover, are complemented by the ability to predict biomass. Along the Front Range of Colorado and Wyoming, there appears to be a consistent linear relationship between cover and biomass for two of the three life-form groups (i.e., grasses and shrubs) in the ponderosa pine zone. Since this zone is used primarily for cattle grazing, the relatively low correlation for forbs is not detrimental for planning purposes where forage production is desired. The Forest Service Range Plant Handbook for the Rocky Mountain Region (FSH 2209.21), lists only one desirable and two intermediate forbs for the ponderosa pine - bunchgrass association, so they do not constitute a significant component of the forage base.

The equations described in this report are meant to be applied in estimating production using mean cover information from one or more ponderosa pine sites along the Colorado-Wyoming Front Range, like those found in Forest Survey data sets, for the purpose of forest planning and other broad-scale ecological investigations.

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# Rocky Mountain Forest and Range Experiment Station

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